DISPLACEMENT CROSS SECTION MEASUREMENTS

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Program Objectives

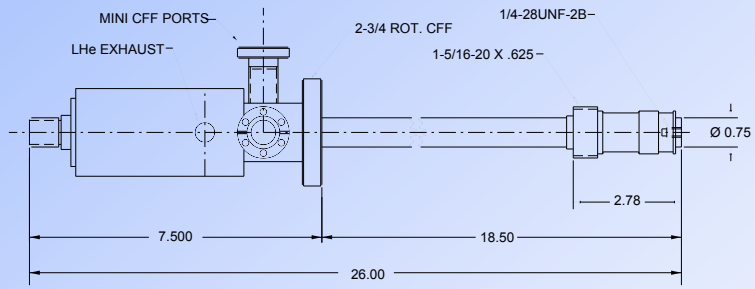
- Critical parameters in the calculation of the magnitude of displacement damage include the damage energy spectrum, defect relaxation and recombination, and the displacement cross section.

- The purpose of the experiments reported here was to make direct measurements of the displacement cross sections for several metals at several irradiation energies for comparison to MCNPX calculations.

- FY2006 effort has unfortunately been restricted by a severe reduction in the anticipated budget (I would call it a “warm standby” budget):
  - Plans for experiments at the BNL NSRL at 200-800 MeV were postponed.
  - Plans were made for an experiment at the BNL cyclotron at 20 MeV; these tests are expected to occur in February.
  - The experiments at 200-800 MeV could still be run, possibly in April, if additional funds were available.

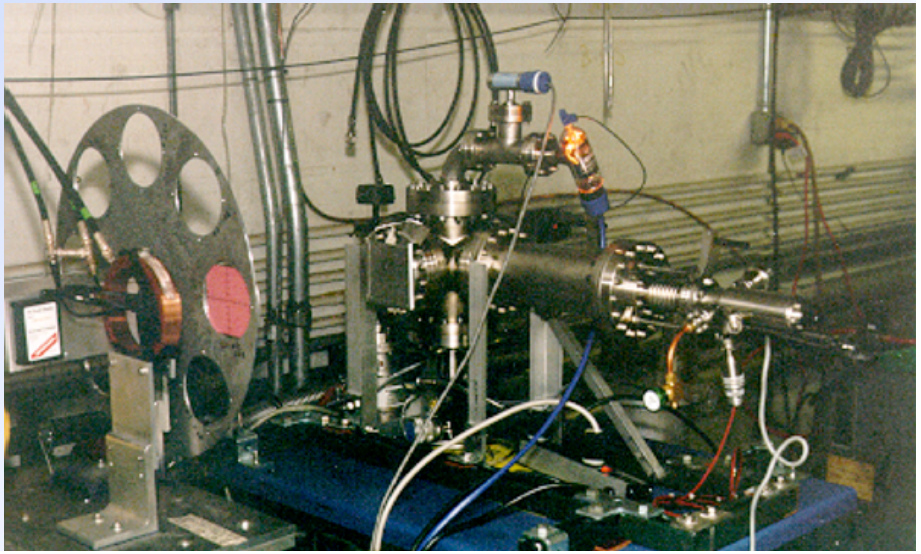
Description of Apparatus and Instrumentation

- Vacuum chamber and cryostat
  - Conflat six-way cross.
  - Vacuum to 10^{-9} Torr.
  - Once-through cryogen.
  - Temperature to 4 K.



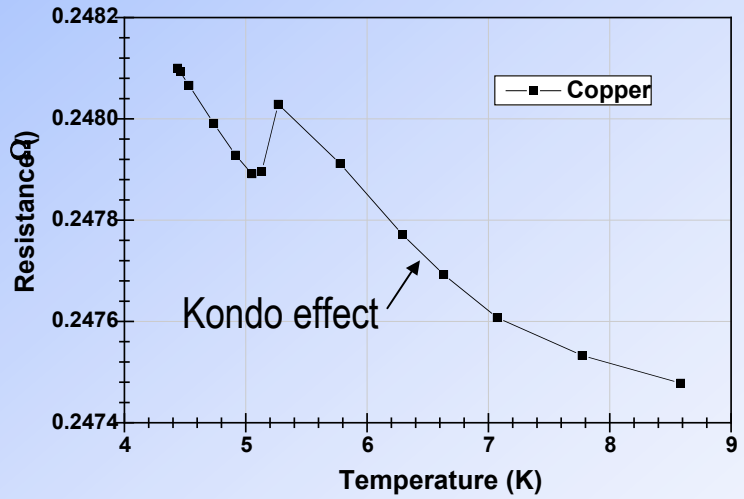
- Radiation damage targets and temperature instrumentation
  - Wire harps of high-purity metal.
  - Mounted to cold head.
  - Cernox temperature sensor.

- Resistance measurement system
  - Kiethley nano-volt/nano-ohm system.
  - Precision four-wire resistance measurements.

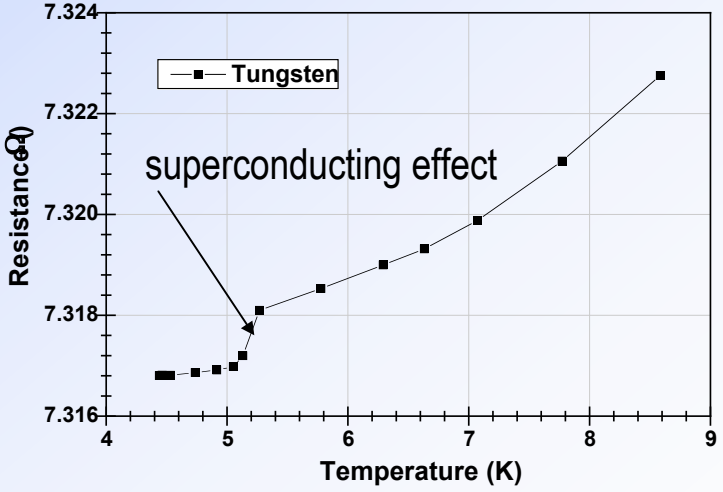


Resistance Characteristics of Radiation Damage Wire Targets

Four wire targets have been prepared for the next series of proton irradiations: copper, tungsten, nickel, tantalum.



The resistance vs. temperature characteristics of each target have been carefully measured from 4 K to 10 K. Both the Kondo effect and superconductivity are apparent in the resistance of the targets, and are accounted for. Resistance characteristics are reproducible.



Displacement Cross Sections for Cu and W at 1.10 GeV and 1.94 GeV

Proton irradiations were conducted at 1.10-GeV and 1.94-GeV for proton doses up to 3×10^{15} protons/cm^2.

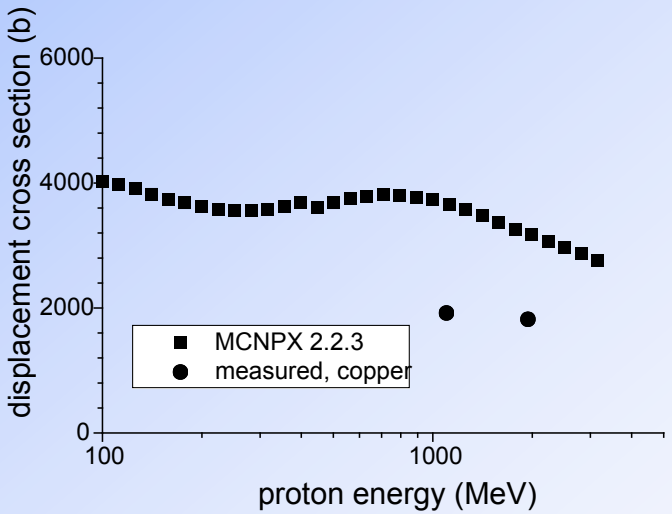
The apparatus demonstrated sustained and stable cryogenic operation at 4.7 K for up to 24 hours.

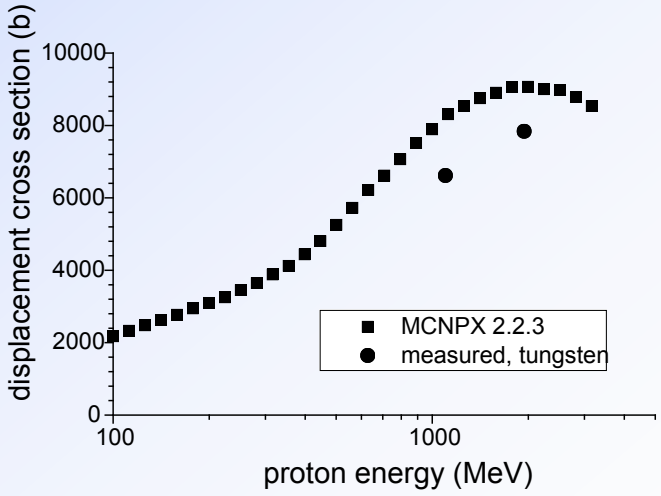
Proton dosimetry was accurate to approximately 1% and the accuracy of temperature measurements was estimated to be on the order of 0.003 K.

Four-wire resistance measurements were performed repeatably to a precision of 1 μΩ.

Resistivity increases due to proton irradiations inferred from the resistance measurements were precise to 10^{-3} nΩ-cm.

Displacement cross sections inferred from the resistivity measurements and the proton dosimetry are compared to predictions from MCNPX 2.2.3.





Previous Results: Displacement Cross Sections for Cu and W at 1.10 GeV and 1.94 GeV

Metal	Proton Energy	$\sigma_{d,\ measured}$	$\sigma_{d,\ calculated}$
	(GeV)	(b)	(b)
Copper	1.94	1820	3195
Copper	1.10	1920	3672
Tungsten	1.94	7840	9067
Tungsten	1.10	6620	8233

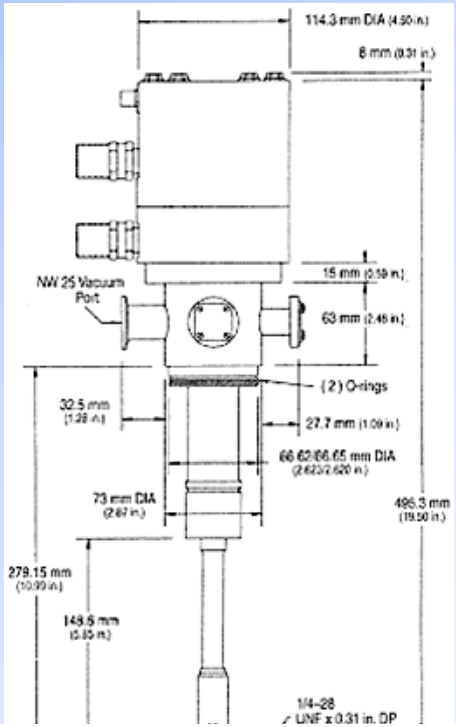
The experimental results for tungsten are now being reevaluated on the basis of recent data in the literature for ρ_f, the resistivity per unit atomic concentration of defects, just uncovered. Indications are that the results will converge.

BNL Japan-Steel-Works 18 MeV Cyclotron Facility

- The JSW cyclotron shown here is available for low-energy proton irradiations.
- Costs to utilize this facility will be free to me; future experiments could be inexpensive.
- Proton energy is fixed at 18 MeV.
- Beam current is in the range 2-20 micro-amps.
- Facility may be attractive for a variety of studies.

Closed-Loop Continuous-Cycle Helium Refrigeration Apparatus for Long-Time Irradiations by Neutrons

- An apparatus similar to the one shown below has been obtained for evaluation for irradiations which would require long duration exposure (up to weeks) to measure displacement cross sections in low-flux neutron beams.
- Apparatus consists of a Displex two-cycle helium refrigerator, turbo-pump vacuum station, and a closed-loop water chiller for the compressor.
- Temperatures down to 12 K have been achieved; unit has a Lake Shore temperature controller to permit operation in the range 12-300 K.
- Newer models can go down to 4 K and up to 400 K.



Status and Future Plans

- The experiments at proton energies of 1.10 GeV and 1.94 GeV have been analyzed; data for Cu and W are in good agreement with MCNPX 2.2.3. Tungsten experimental results are being reevaluated on the basis of newly uncovered information in the literature.

- The next series of measurements at a proton energy of 18 MeV will be conducted in February. Difficulties with the JSW cyclotron vacuum and RF systems have been corrected.

- Proton irradiations could be conducted at the NSRL at 200-500-800 MeV if the budget were to allow. This would give us data at 18 MeV, 200 MeV, 500 MeV, 800 MeV, 1.10 GeV and 1.94 GeV protons for four metals.

- Future FY2006-2007 work will concentrate on the measurements of displacement cross sections for neutrons. A closed-loop refrigeration system is under evaluation, which will permit irradiations with low flux neutron sources for days or weeks.

- Measurements of neutron displacement cross sections could support both AFCI and Gen-IV.